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DEVELOPMENT AND TEST OF A SOD-REMOVAL PROCEDURE  
FOR MOIST LAWNS CONTAMINATED BY SIMULATED FALLOUT

by

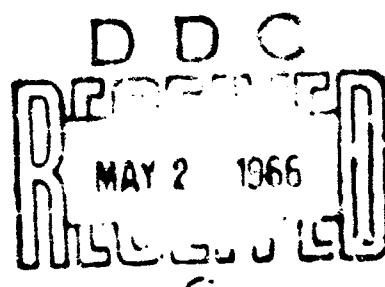
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ADMINISTRATIVE INFORMATION

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SUMMARY OF RESEARCH REPORT

DEVELOPMENT AND TEST OF A SOD-REMOVAL PROCEDURE FOR MOIST LAWNS  
CONTAMINATED BY SIMULATED FALLOUT

USNRDL-TR-965, dated 10 April 1965 by W. C. Cobbin and W. L. Owen

## INTRODUCTION

In the event of nuclear attack, fallout-contaminated lawns could present a difficult radiological problem. The surface texture and configuration of lawns render them natural traps for fallout particulate. Considerable portions of populated areas are comprised of lawns, whether these be residential, business, or industrial districts. Hence lawns represent a serious potential hazard to a significant portion of the population in these areas.

The procedures previously developed for the reclamation of extensive unpaved land areas are not necessarily applicable to lawns for two reasons. (1) Many lawns are made inaccessible to heavy motorized equipment by such obstructions as buildings, trees and curbed walks; (2) Most earth-moving equipment removes more soil than is necessary, thereby creating large disposal problems.

Sod cutting and removal methods offer a means for conveniently reclaiming lawn areas. Although sod cutters have never been used in radiological reclamation, their capability for removing sod has been established in the landscaping industry. For these reasons a commercially available sod cutter was tested on lawns contaminated with simulated fallout, using optimum machine adjustments and manual removal procedures.

## PURPOSE AND OBJECTIVES

The general purpose of the experiment was to determine the effectiveness and effort required to reclaim lawns contaminated by radioactive fallout, through the use of a sod-cutting machine in an optimized sod removal procedure. Specific objectives were:

1. To reduce the sod removal effort required, by (a) minimizing the mass layer of soil that must be removed and (b) developing an optimum procedural combination of motorized sod cutting and manual removal.
2. To measure the effect of fallout particle sizes and mass loadings on reclamation effectiveness.

## SCOPE

The sod cutter experiment was divided into two parts. A preliminary part consisted of 13 tests using non-radioactive fallout simulant, which met the first objective by establishing machine and operational parameters, surface conditions and removal techniques. The principal part consisted of 12 tests using radio-traced fallout simulant, which met the second objective by using the parameters previously established to observe the effect of fallout properties on removal effectiveness.

In the principal tests, evaluation of reclamation effectiveness was limited to one optimum set of machine parameters (a forward speed of 1 mph and a cutting depth of 1-1/2 in.) and one operational procedure. Two types of lawn area were provided: (1) unconfined areas accessible to heavy equipment, and (2) confined areas inaccessible to heavy equipment because of obstructions such as buildings, trees, and raised sidewalks. Twelve contaminating conditions were selected, using four particle size ranges of 44-88  $\mu$ , 88-177  $\mu$ , 177-350  $\mu$ , and 350-700  $\mu$ , each at three initial mass loadings of 25 g/ft<sup>2</sup>, 50 g/ft<sup>2</sup>, and 100 g/ft<sup>2</sup>.

## FINDINGS AND HIGHLIGHTS

Sod cutting and removal effectiveness are governed by two classes of factors, environmental and operational. Environmental factors include: surface conditions of moisture content and of presence and frequency of rocks, large roots, and other objects near the surface; area accessibility (confined or unconfined); and fallout properties of initial mass loading and particle size. Operational factors include: forward speed, depth and width of cut, size and weight of rolled up sod strips, distance to the disposal site, and capacity of the carrier used for disposal of the waste material.

The highest degree of removal effectiveness achieved (0.2 g/ft<sup>2</sup> residual mass) was on unconfined areas, under surface conditions of medium moisture content (72-96 hr after normal watering), at low initial mass loadings (25 g/ft<sup>2</sup>). The poorest effectiveness obtained (1.7 g/ft<sup>2</sup> residual mass) was in confined areas, under overly moist surface conditions (24-48 hr after heavy rains).

In general the test results show the mass remaining can be reduced to 1 to 2.5 % of the initial mass loading for an investment of 50 to 80 (man-min)/(10<sup>3</sup> ft<sup>2</sup>) on the unconfined area and 80 to 125 (man-min)/(10<sup>3</sup> ft<sup>2</sup>) in the confined areas.

## CONCLUSIONS

The combined operational performance of sod cutting and removal was found to be an effective procedure for lawn reclamation under the conditions studied.

Effective removal can best be accomplished by manually rolling the sod into conveniently sized rolls and loading it into carriers for disposal.

Reclamation effectiveness is governed by initial mass loading, effort expended, and condition of the lawn area. For instance:

1. For a given investment of effort, residual mass is a direct function of initial mass loading. That is, residual mass tends to be smaller when initial mass loading is small.
2. Lawn conditions adversely affecting sod cutter performance, in order of decreasing importance, include: (a) confinement of areas due to size, shape and obstructions; (b) excessive moisture in the sod layer; (c) concentration of rocks and/or woody roots near the surface; and (d) grass root system and voids in turf.

Compared to the above factors, the effects of particle size were so slight as to be considered insignificant.

Using effort as a criterion, accessible lawn areas were reclaimed more efficiently than confined areas.

Of the three phases comprising the lawn reclamation procedure, removal is the controlling phase when considered in terms of effort required.

Comparisons with previous lawn reclamation tests show the sod cutting method to require less effort than shoveling but more effort than tractor scraping.

## RECOMMENDATIONS

It is recommended that

1. Sod cutters be used in confined areas where other heavy motorized equipment cannot operate efficiently.
2. The feasibility be investigated of some design changes such as (a) including a reverse gear in the transmission; (b) providing some means of moving a cut strip of sod a few inches to one side. The latter

would enable the operator to continue the cutting phase of the operation without first removing each cut strip.

3. One of the larger width (18 in. or 24 in.) cutters be evaluated for achieving more economical operational rates.

4. These studies be extended to include tests on unattended (dry and unmowed) lawns, such as would be encountered in a dry climate upon emergence from shelter two or three weeks after a nuclear attack.

## ABSTRACT

A sod-cutting machine was evaluated for its usefulness in the radiological reclamation of small lawn areas - some of which were confined by sidewalks, trees and buildings. Fallout conditions were simulated by contaminating lawn test areas with radio-traced sand. Nominal particle size ranges of 44-88  $\mu$ , 88-177  $\mu$ , 177-350  $\mu$  and 350-700  $\mu$  were used. This fallout simulant was dispersed at nominal concentrations of 25, 50 and 100 g/ft<sup>2</sup>, respectively.

Reclamation effectiveness of sod cutting was dependent upon machine factors (blade depth), soil characteristics (moisture content) and fallout simulant properties (mass loading). The least effective sod removal results were obtained in confined lawns with high moisture content and heavy rock concentrations. The best sod cutting and removal effectiveness results were obtained on more accessible lawns having less moisture content and only a light concentration of rocks. Simulant particle size was found to have little, if any, effect upon reclamation performance either with respect to effort required or removal effectiveness achieved.

## SUMMARY

### Problem

Lawns contaminated by fallout from nuclear attack present a difficult reclamation problem. Not only are lawns efficient fallout traps, but they are often inaccessible to heavy equipment suitable for reclamation of open areas. A sod-cutting machine, therefore, was investigated as a means for developing an efficient procedure for effective removal of lawn sod together with the radioactive fallout.

### Findings

Using radionuclide-traced sand to simulate dry fallout from nuclear weapons detonated on a land surface, effectiveness and effort data were obtained for one optimum combination of sod-cutting machine parameters, operational parameters, and one manual removal method. This optimum combination was tested under several environmental conditions including mass levels of 25, 50 and 100 g/ft<sup>2</sup>, and particle size ranges of 44-88  $\mu$ , 88-177  $\mu$ , 177-350  $\mu$  and 350-700  $\mu$ . Lawn test areas were kept as nearly the same as possible with respect to turf condition such as moisture content and height of grass.

The combined operational performance of sod cutting and removal was found to be an effective procedure for lawn reclamation under the conditions studied.

Effective removal of the cut sod can best be accomplished by manually rolling the sod into conveniently sized rolls and loading it into carriers for disposal.

Reclamation effectiveness (residual mass) is a direct function of effort expended and an inverse function of the initial mass loading. Fallout particle size has little effect, if any.

Lawn conditions adversely affecting sod cutter performance are, in order of decreasing importance; (a) confinement of area due to size, shape and obstructions; (b) excessive moisture in the sod layer; (c) concentration of rocks and/or woody roots near the surface; and (d) poor grass root system and voids in turf.

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## CHAPTER 1

### INTRODUCTION

Recovery from a land surface nuclear weapon attack requires a critical appraisal of the fallout event, through which is determined the application and sequencing of radiological countermeasures to be used during the recovery period. Reclamation is one of the major countermeasures to be used during the operational recovery phase. The countermeasure procedure to be used on a particular target component depends upon, besides the fallout characteristics, the nature of the surface in relation to the materials and equipment available.

Among the various types of components within a fallout target, lawns present an especially difficult radiological problem. The surface texture and configuration of lawns render them natural traps for fallout particles. Lawns comprise considerable portions of populated areas, whether they be residential, business or industrial districts. Hence lawns represent a serious potential radiation hazard, and therefore, should rank high on the recovery schedule if nearby locations are to be made safe for inhabitants.

Lawns, like other unpaved ground surfaces, require surface-destructive reclamation methods. That is, a thin top layer of earth is removed along with the unwanted fallout and is safely disposed of. Procedures developed at Stoneman II<sup>1</sup> for extensive unpaved open areas are not practical for lawn areas for several reasons: (a) The heavy earth-moving equipment used in some of these procedures removes more base soil than is necessary for reclamation of lawns, thereby increasing the disposal problem. (b) The agricultural equipment used in other methods does not provide the reclamation effectiveness required. (c) Most lawns are inaccessible to either type of large-scale motorized equipment. (d) Purely manual methods require much manpower and operational time, and expose crews to excessive radiation.

Sod cutters offer a promising means of lawn reclamation. Their capability as sod-cutting tools has been established in the landscaping industry. Sod cutters are commonly used in resodding playgrounds, golf courses, and cemeteries. However, since no reclamation history exists for these machines, a commercially available sod cutter was tested to

determine its general reclamation effectiveness and observe its utility in confined areas.

Previous investigations of the reclamation of unpaved land used both heavy earth-moving equipment and manual methods. Operation Stoneman II 1958<sup>1</sup> included the reclamation of extensive grassy areas by the use of motorized graders, scrapers, and bulldozers. In Target Complex Tests I,<sup>2</sup> II,<sup>2</sup> and III<sup>3</sup> lawn areas were reclaimed with hand shovels and wheel barrows, agricultural scrapers, road graders, and end-loaders.

This equipment was used individually or in combination in the following ways: (a) Burying the fallout by turning under a thick layer of soil or covering it with a clean layer of soil. (b) Removing the fallout (along with whatever soil was picked up with it) and transporting it to a safe disposal area. The efficiency of the heavy equipment was seriously reduced in the confined lawn areas, thereby requiring extensive manual cleanup. Although removal effectiveness did not suffer necessarily, extensive manpower was required.

#### 1.1 PURPOSE AND OBJECTIVE

The general purpose of the experiment was to determine optimum sod-cutting performance characteristics and sod removal procedures for the effective reclamation of lawn areas contaminated by radioactive fallout. In support of this, the specific test objectives were:

1. To reduce the effort required, by: (a) minimizing the mass of sod layers that must be removed, and (b) developing an optimum procedural combination of motorized sod cutting and manual removal.
2. To measure the effect of fallout particle size and initial mass loading on reclamation effectiveness.

#### 1.2 APPROACH

Since sod cutting machines are designed only for non-radiological purposes, a complete procedure had to be developed integrating cutting, removal, and disposal. The sod cutter experiment was divided into two parts. A preliminary part consisted of 13 tests using non-radioactive

fallout simulant, described in Appendix A. The principle part consisted of 12 tests using radio-traced fallout simulant. The former met the first objective by establishing machine and operational parameters, surface conditions, and removal techniques to be used in the principal part. The latter met the second objective by measuring the effect of fallout properties on removal effectiveness under conditions established in the preliminary tests.

#### 1.2.1 Scope

The evaluation of reclamation effectiveness (the principal tests) was limited to one optimum set of machine parameters (described in section 2.1.2) and one operational procedure (described in section 2.2.1). Two types of lawn areas were provided: (a) unconfined areas accessible to heavy equipment; (b) confined areas inaccessible to heavy equipment because of obstructions such as buildings, trees, and raised sidewalks.

Twelve contaminating conditions were selected consisting of four particle size ranges and three nominal initial mass loadings. The following table indicates the combinations of size range and mass loading according to test number.

Particle Size ( $\mu$ )	Initial Mass Loading (g/ft <sup>2</sup> )		
	25	50	100
44- 88	7	8	9
177-350	1	2	3
350-700	4	5	6
88-177	10*	11	12

\*Entries indicate test numbers.

## CHAPTER 2

### PREPARATIONS FOR AND CONDUCT OF TEST

#### 2.1 BASIC PRINCIPLES OF RECLAIMING MOIST LAWN AREAS

##### 2.1.1 General Description of the Sod Removal Process

Reclamation of moist lawn areas covered with radioactive particulate fallout from a land surface weapon detonation involves the removal of a thin layer of earth and sod along with the unwanted fallout particles, and the safe disposal of the waste material. It is reasonable to expect that lawns may be effectively reclaimed by the use of motorized sod cutting machines and manual removal methods. Sod cutters shave thin uniform layers of moist sod and leave it in place with minimum spreading about of the fallout particles. Manual removal consists of cutting the strips into convenient lengths, rolling the strips into small tight rolls (to retain the fallout), and placing them in carriers for disposal. Because of all this handling a certain amount of fallout material will be spilled, leaving a residual radiation source.

##### 2.1.2 Test Parameters

Several factors of two classes influence reclamation effectiveness, environmental and operational.

Environmental factors describe two sets of conditions, those of the physical site and the radiological.

###### Physical Site Factors:

- a. Accessibility - open or confined
- b. Shape and size of lawn areas
- c. Slope and topography (flat or hilly)
- d. Lawn condition - length of grass, thickness and homogeneity of the turf
- e. Soil condition - degree of compaction, moisture content, frequency of rocks and large roots.

Radiological Factors:

- a. Mass loading
- b. Particle size range, size distribution
- c. Leaching and exchange effects due to weathering.

Operational factors describe two sets of conditions, those inherent in the reclamation equipment and in the procedure.

Equipment Factors:

- a. Depth and width of cut
- b. Speed and maneuverability of sod cutter
- c. Fuel consumption
- d. Capacity of loading and hauling equipment.

Procedural Factors:

- a. Operational sequencing and timing
- b. Size and weight of rolled sod
- c. Operational rate and effort.

## 2.2 TEST PROCEDURE

### 2.2.1 Principal Tests

Each of the principal tests was conducted on lawns of certain moistness (Appendix A), with radiotraced fallout simulant at initial mass levels and particle size ranges required by the planned test conditions (Table 1.1). For each test, simulant of a specific particle size range was dispersed at a specific initial mass level as described in Section 2.6. Radiation background measurements were made as described in Section 2.7.1.

The reclamation phase consisting of cutting, manual removal, and disposal, was run on a nominal 500 ft<sup>2</sup> test area in the following sequence:

1. Strips 1 ft wide were cut with the sod cutter, beginning at the edge (Fig. 2.1) of the test area.
2. The strips were cut transversely with a manual edger into sections 9 ft long for easier removal as the sod cutter progressed.

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Fig. 2.1 Sod Cutter in Operation. Note uniformity in depth and width of cut.

3. The sections were rolled into small tight rolls (Fig. 2.2) to retain the fallout and placed in the payloader (Fig. 2.3).

4. The payloader was driven to the disposal area and dumped at convenient intervals.

5. Residual radiation measurements were made as described in Section 2.7.

The above procedure was duplicated for each test to assure uniformity in the overall experiment.

#### 2.2.2 Preliminary Tests

The preliminary part of the experiment was conducted using inert simulated fallout at nominal mass loadings of 25, 50 and 100 g/ft<sup>2</sup>, with 44-88  $\mu$ , 88-177  $\mu$ , 177-350  $\mu$  and 350-700  $\mu$  particle size ranges. No effectiveness data was taken since only visual observations were made. Machine adjustments, surface conditions of moisture content, and optimum operational procedural sequences were determined by these tests and are described in Appendix A.

As a result of these preliminary tests, a fixed combination of forward speed and depth of cut was established for the principal tests. A single forward speed of approximately 1 mph was selected because it could be maintained through a given test run without discomfort to the sod cutter operator and without loss of maneuverability. This speed was within the range specified by the manufacturer.

A depth of cut of 1-1/2 in. was selected. This depth minimized the amount of bulk (sod and soil) that had to be disposed of, while providing the necessary thickness for rolling and handling, thus reducing both removal effort and disposal effort.

#### 2.3 DESCRIPTION OF THE SOD CUTTER

Detailed specifications of the Ryan Jr. sod-cutting machine\* are given in Appendix E. Some general features that are common to most motorized sod cutters are presented here (see Fig. 2.4).

\*Ryan Landscaping Equipment Co., 871 Edgerton St., St. Paul 1, Minnesota.

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Fig. 2.2 Manually Rolling Cut Sod. Long sod strips were cut transversely by man with long-handled cutter. Pay-loader was positioned nearby to facilitate loading.

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Fig. 2.3 Loading Sod Rolls Into Payloader Bucket for Transport to Disposal Area. RadSafe monitor is measuring the radiation level due to concentration in one place of fallout simulant on sod.

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Fig. 2.4 Sod Cutter (Ryan Jr.), 12-in. Blade. View of under side showing cutting blade to left of wheels.

The sod cutter is powered by a 4-hp, 4-cycle gasoline engine. It has a one-forward-speed transmission with neutral gear. The 12-in. wide blade may be preset for a depth of cut ranging from 1/4 to 2-1/2 in. depending upon sod conditions. The blade also may be tilted forward or backward to provide for a more uniform depth of cut. This adjustment reduces the tendency of the blade to resurface when cutting through a heavy concentration of rocks. Engine clutch and throttle controls are conveniently located between the handle bars.

#### 2.4 DESCRIPTION OF TEST AREA

Two lawn areas were developed and maintained for several months to achieve lawns common to the United States. One was an easily accessible area of 5600 ft<sup>2</sup> (approximately 40 x 140 ft) which was divided into 9 small test sections each of 504 ft<sup>2</sup> (14 x 36 ft). Each test section was laid out with 18 monitoring points (see Fig. 2.5), located to provide complete coverage by the shielded gamma detector. Radiation measurements were made with the detector at these designated points to determine reclamation effectiveness.

An area typical of residential lawns, of approximately 2000 ft<sup>2</sup> (Fig. 2.6), and with buildings, trees, and sidewalks, was used for the confined lawn tests. This area was divided into 3 test sections by the paved surfaces in the area. Monitoring points were located on these areas similar to those described above.

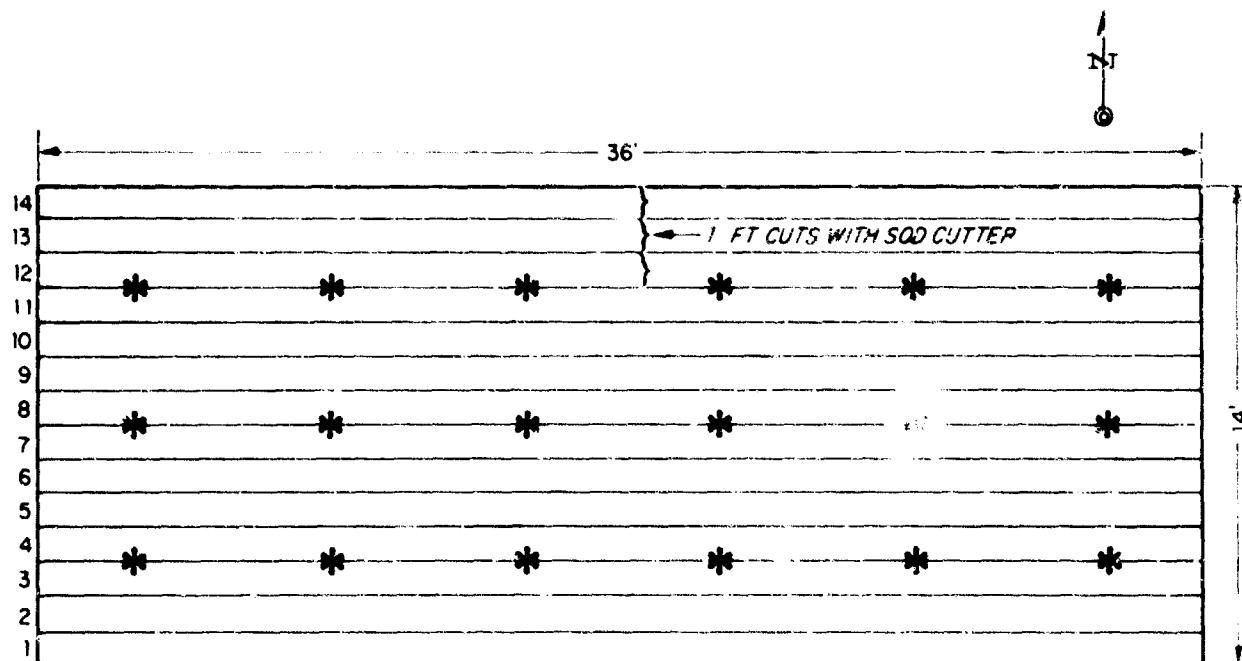
A small portion of these general test sections (approximately 1500 ft<sup>2</sup>) was used for the preliminary tests described in Appendix A.

#### 2.5 PRODUCTION OF FALLOUT SIMULANT

##### 2.5.1 Bulk Carrier Material

The bulk carrier material was produced from Del Monte and Wedron (river bottom) sand. The raw sand was processed with a Novc sieving machine. The nominal particle size ranges were separated by a sequence of passes of the raw sand through the proper sized screens. Quality control was maintained by frequent sampling and sieve analysis. These procedures are described in References 4 and 5.

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\* = MONITORING POINTS

Fig. 2.5 Typical Test Section ( $504 \text{ ft}^2$ ) on Lawn Area Showing Monitoring Stations and Cuts by Sod Cutter.

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Fig. 2.6 Residential Lawn Test Area, Confined by Buildings, Trees, Walks and Paved Surfaces. For Tests 10, 11 and 12.

### 2.5.2 Radioactive Bulk Carrier Material

The bulk carrier material was tagged with trace amounts of radio-nuclide La<sup>140</sup>. The tagging process<sup>5</sup> consisted of spraying a known amount of solution of radionuclide onto the surface of the bulk carrier material.

La<sup>140</sup> was selected to tag the sand for several reasons: (a) The relatively short half-life (40.2 hr) permits repeated testing within the same general area, without creating an excessive build-up in background radiation. (b) Adequate facilities are available at Camp Parks<sup>2,3</sup> for preparation of this simulant.

A remodeled simulant hopper and concrete shield (Fig. 2.7) was used in several stages of the handling of the radioactive simulant. (a) It provided a means of metering out the desired amount of simulant needed for a particular experiment. (b) It provided a storage place for the simulant until needed for subsequent tests. (c) The shield protected test personnel when they were transporting simulant to test areas and filling spreaders.

## 2.6 DISPERSAL OF FALLOUT SIMULANT

A hand-operated lawn spreader\* was used to disperse the fallout simulant. Uniform dispersal was achieved by extensive calibration of the spreader feeder controls for different particle sizes. Different nominal particle size ranges require different rates of deposition to achieve a given initial mass loading. The average initial mass loading in grams per square foot was determined by weighing the loaded spreader both before and after dispersal and dividing the difference by the area covered. Close control of mass levels as well as uniform dispersal was conveniently achieved by this method. Residual mass loadings were determined from radiation measurements described in the following section.

## 2.7 MEASUREMENT TECHNIQUE

### 2.7.1 Radiation Measurements

Radiation measurements were used to determine the effectiveness of the reclamation procedure in terms of initial and residual mass loadings.

\*Manufactured by O. M. Scott and Sons, Marysville, Ohio (see Fig. 2.7).

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Fig. 2.7 Simulant Hopper with Concrete Shield. View of hopper is partially blocked by shield. Metering nozzle is oriented so that operator discharges simulant while shielded from bulk of contaminant.

Radiation levels on test areas, before and after reclamation, were measured with a mobile shielded gamma scintillation detector<sup>6</sup> (Fig. 2.8). The principle detection element of this instrument was a 1-in.-diameter, 1-in.-thick, NaI(Tl) scintillation crystal coupled to a photomultiplier tube. These were so positioned within a 4-in.-thick lead shield that the center of the detector was 1 meter above the ground. A collimated 1-in.-diameter aperture subtending a 14° cone of view permitted entrance of radiation into the sensitive volume. The power supply, associated electronics, and print-out system, as well as the shielded detector, were trailer-mounted.

To assure consistent and reliable radiation measurements, a three-step routine was followed for all surveys:

1. A Co<sup>60</sup> radiation standard was counted to determine instrument response.
2. Two 1-min. counts were made and recorded at each of 18 pre-determined survey stations.
3. The Co<sup>60</sup> standard was again counted to check and correct for any instrument drift during the survey.

This procedure was applied to background surveys prior to dispersal, initial surveys immediately after dispersal, and residual surveys after reclamation. At the beginning of each day a 15 to 30-min. instrument warm-up period was required before the first survey was made.

The measurements obtained at each monitoring location on the test area are presented in Appendix C. The data have been corrected to a common time to account for radioactive decay and corrected for background. The method used to convert the radiation measurements to mass units is presented in Appendix D.

#### 2.7.2 Physical and Radiological Property Measurements of the Simulant

Physical and radiological property measurements were made to determine and control the fallout environment being simulated. Particle size measurements were made using a Rotap machine\* and standard Tyler sieves. Six to nine sieves and a pan were stacked in descending standard mesh sizes to analyze the particle size ranges of the material. A 100-gram sample of material was placed on the top sieve and agitated for 10 min, the particles sifting through the sieves. Each fraction retained on a sieve was weighed to determine the size distribution within that nominal size range.

\*W. S. Tyler, Co., Cleveland, Ohio.

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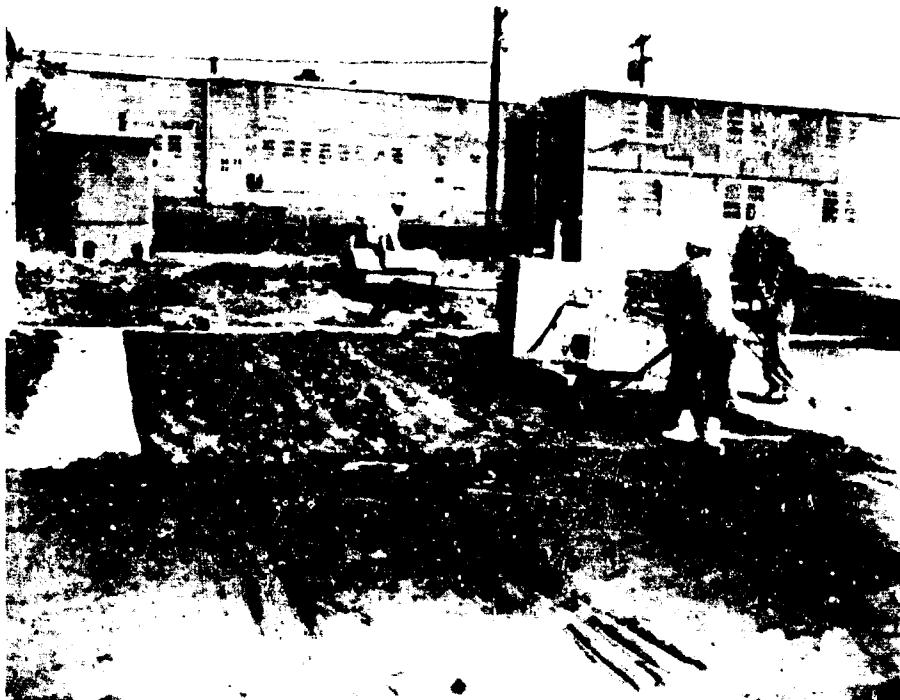


Fig. 2.8 Mobile Shielded Gamma Radiation Detector  
Measuring Radiation Level on Test Area.

A 4x ionization chamber (see Fig. 2.10, Ref. 4) was used to determine the specific activity ( $\mu\text{c/g}$ ) of the individual sized simulant fractions and to follow the decay of samples from each simulant batch.

The results of the sieving and radio-analysis are given in Appendix B. In addition, the relationship between specific activity and particle size is evaluated.

### 2.7.3 Time and Motion Studies

Detailed time measurements were recorded from each phase of the sod removal experiment. These phases included sod cutting, sod removal, and hauling of soil. Support time and lost time were also noted. This information was obtained to determine the time and effort required to complete each test and was used to construct a dose rate history curve (section 3.5.1).

## CHAPTER 3

### RESULTS AND DISCUSSION

#### 3.1 PRESENTATION OF RESULTS

The results of the sod removal tests are presented in Table 3.1. The values were reduced from the raw data given in Appendix B. The average initial and residual mass levels,  $M_0$  and  $\bar{M}$ , in g/ft<sup>2</sup>, were computed by the method discussed in Appendix D. The averaged residual fraction  $\bar{F}$ , expressed as the percent mass (or count) remaining is

$$\bar{F} = 100 (\bar{M}/ M_0) = 100 (\bar{R}/ \bar{I}) \quad (1)$$

The initial count rate, I, and the residual count rate, R, from which  $\bar{F}$  was obtained, are given in Appendix B.

The 95 % confidence limits (CL) shown in Table 3.1 were obtained by the formula:\*

$$CL = \bar{M} \pm t s_{\bar{M}}$$

$$CL = \bar{M} \pm t (s_M / \sqrt{N})$$

where  $\bar{M}$  = average residual mass

t is from the student t distribution

$s_{\bar{M}}$  = standard deviation of the mean  $\bar{M}$

$s_M$  = standard deviation of individual M values

N is the number of M values observed - in most cases 18

Effort E, in the last column of Table 3.1, is a measure of the work required per unit area as determined from the number of men or machines involved. In this report effort is expressed as man-min/10<sup>3</sup> ft<sup>2</sup>.

\*W. G. Dixon, F. G. Massey Jr., *Introduction to Statistical Analysis*, 1st edition. New York, McGraw-Hill, pp. 108, 1951.

TABLE 3.1

Results of Sod Cutting and Removal Tests in Terms of the Mean Values of the Pertinent Variables

Test No.	Initial Mass $\bar{M}$ (g/ft <sup>2</sup> )	Residual Mass			Residual Fraction			<u>Combined Effort*</u> $\bar{E}$ mah-min 10 <sup>3</sup> /ft <sup>2</sup>
		$\bar{M}$ (g/ft <sup>2</sup> )	95% C.L. Upper	Lower	$\bar{F}$ (%)	95% C.L. Upper	Lower	
Nominal Particle Size Range: 177-350 $\mu$								
1	25.2	0.67	0.82	0.52	2.7	3.9	1.4	79.3
2	51.8	0.91	0.96	0.86	1.8	2.4	1.1	50.3
3	92.3	1.41	1.63	1.19	1.5	2.0	1.0	53.5
Nominal Particle Size Range: 350-700 $\mu$								
4	21.6	0.22	0.27	0.18	1.0	1.5	0.6	54.5
5	50.0	0.73	0.88	0.57	1.5	2.1	0.8	61.0
6	94.0	2.06	1.24	0.88	1.1	1.5	0.7	63.9
Nominal Particle Size Range: 44-88 $\mu$								
7	23.4	0.21	0.25	0.18	0.9	1.2	0.6	51.1
8	50.0	0.42	0.50	0.35	0.8	1.1	0.6	55.8
9	109.0	1.09	1.31	0.86	1.0	1.4	0.6	60.0
Nominal Particle Size Range: 88-177 $\mu$								
10	24.0	0.40	0.48	0.32	1.7	2.3	1.0	81.3
11	60.1	0.64	0.70	0.58	1.0	1.3	0.8	115.2
12	98.5	1.73	2.21	1.24	1.7	2.7	0.8	124.4

\*Includes the sum of cutting effort and removal effort only. Hauling effort, which has been excluded, is given in Table 3.3.

## 3.2 RECLAMATION PERFORMANCE

A number of factors that could affect the performance of lawn reclamation by sod cutting techniques were listed in Section 2.1.2. Certain of the more critical factors were observed during the tests, and they are discussed in the following sections.

### 3.2.1 Removal Effectiveness

One measure of performance is lawn removal effectiveness. Table 3.1 indicates this quantity in two ways. The absolute effectiveness is represented by the residual mass  $M$ . The relative effectiveness is given by the residual fraction  $F$  as calculated from Eq. 1. These residual fractions are confined to a very small interval ranging from 0.8 to 2.7 percent. For this reason there is no apparent correlation between relative effectiveness  $F$  and such tabulated quantities as mass loading  $M_0$  or effort  $E$ . However,  $M$  values for absolute effectiveness show some very definite trends.

### 3.2.2 Mass Loading Effects

A cursory check of the mass entries in Table 3.1 for each particle size range reveals that residual mass  $M$  varies directly as mass loading  $M_0$ . The trend depicted in the  $M$  versus  $M_0$  plot in Fig. 3.1 further substantiates this relationship. That is, the tendency of the data points to describe a gradual path from lower left to upper right demonstrates that absolute effectiveness becomes poorer ( $M$  gets larger) with increased initial mass loading.

Note that the solid data points of Fig. 3.1 identify those tests for which an unusually large amount of effort was required. Effort effects are discussed in Section 3.3.

### 3.2.3 Particle Size Effects

Figure 3.2 shows the variation of residual mass with particle size for the three nominal mass loadings tested. The ascending-descending form of the curves appear to be attributable to particle size changes. However, the lack of any consistent ordering of the data points in Fig. 3.1 according to particle size does not confirm such a conclusion. The humped trend occurring in the curves of Fig. 3.2 at a particle size range of  $177\text{-}350 \mu$  was more probably due to a combination of operator inexperience and poor turf conditions. The three tests run at this size range

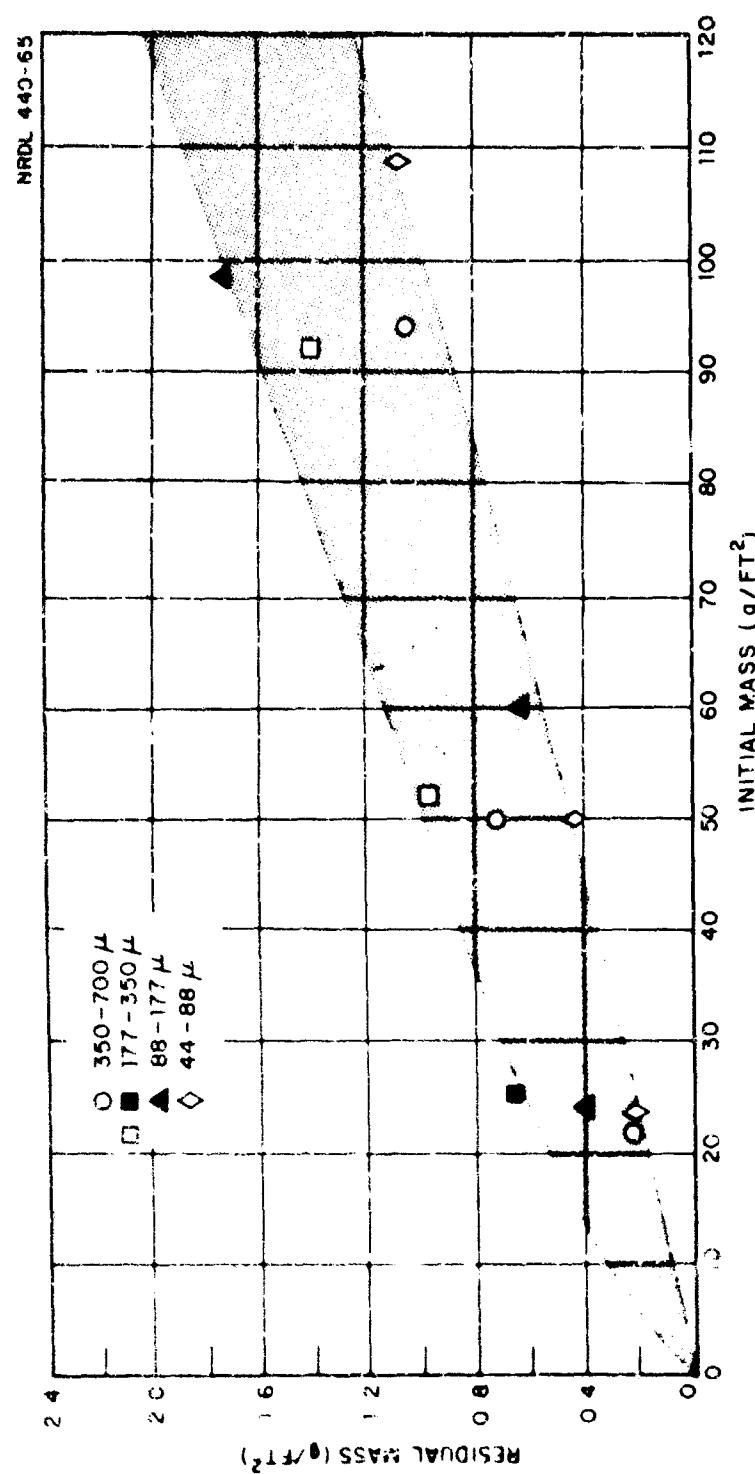
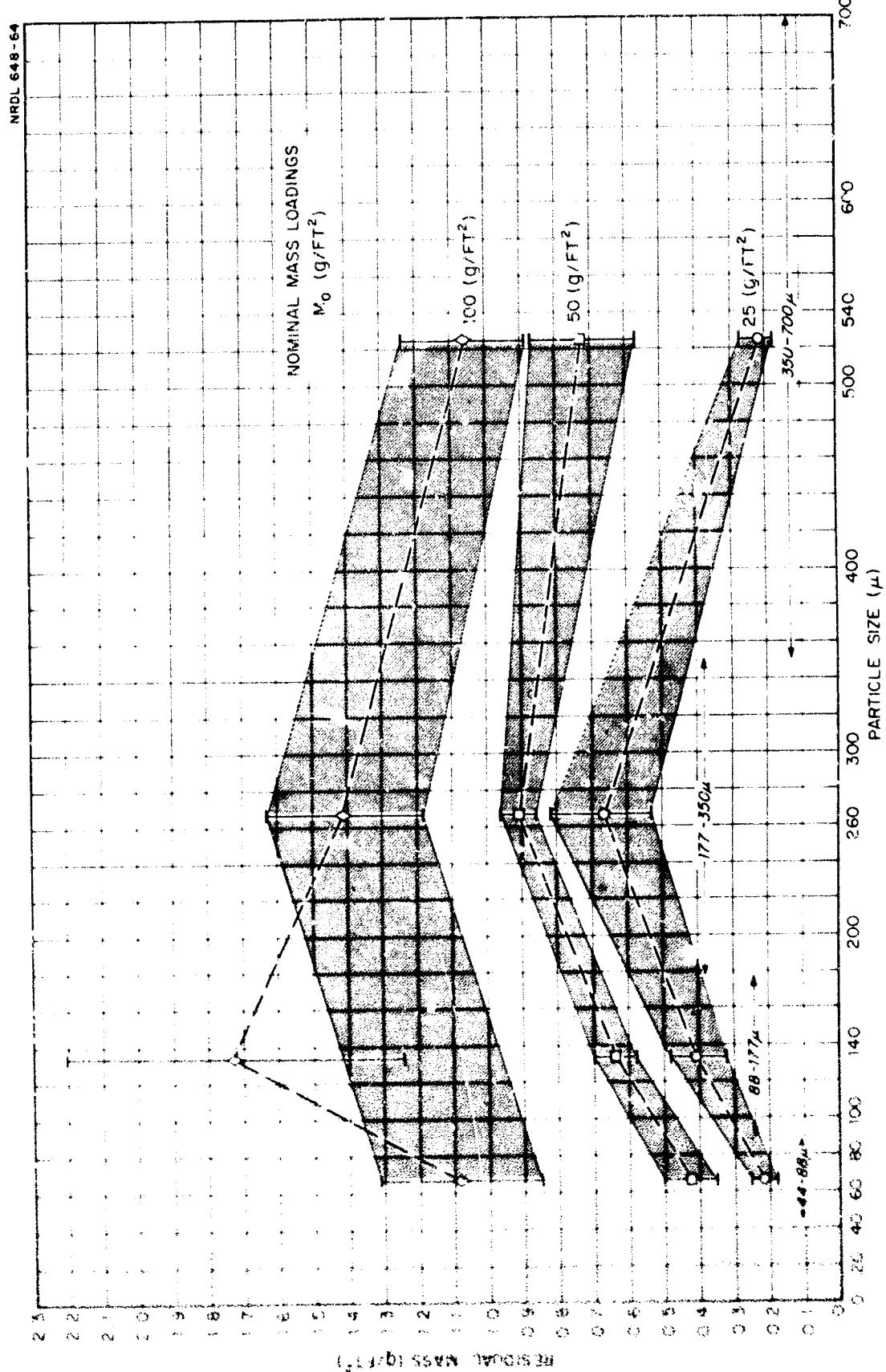


Fig. 3.1 The Influence of Mass Loading on Absolute Removal Effectiveness



**Fig. 3.2** Apparent Trends in the Relationship Between Residual Mass and Particle Size Mid-Range.

were the first in the series. As a result, the sod cutting and removal operation had not reached peak efficiency. Also the presence of thin spots in the turf and large rocks in the soil increased the frequency of spills.\*

The maximum data point of the 88-177  $\mu$  particle size range was ignored in constructing the upper shaded band, because its confidence interval is approximately 60 % of the value itself. However, several factors could have contributed to the higher residual mass value for this test. These include area confinement, excessive moisture, and obstructions demanding more cuts and rolls per square foot, hence more contaminant spills.

Note that the shaded areas denote distinctly separated trends which can be identified according to mass loadings. The manner in which they are ranked in the ordinate direction again shows that residual mass increases with mass loading.

### 3.3 TIME AND MOTION STUDY

#### 3.3.1 Reclamation Effort

Table 3.2 shows the reclamation effort required for each test expressed in man-min/ $10^3$  ft $^2$ . The body of the table shows a breakdown of the effort expended and the number of men involved for each phase of the test operation. The last column gives hauling effort in terms of unit distance to the disposal site.

The tabulated entries have been grouped to show any effects due to either particle size range or to differences in area accessibility. As would be expected, comparisons of the average values calculated for each of the three size ranges involved in the open area tests show no significant change in effort with particle size. Obviously no such observations can be drawn from the results on confined areas, since only the 177-350  $\mu$  size range was used, but no change would be expected.

comparison of the average effort values given in Table 3.2 for the three phases of the sod removal experiments shows that open areas are more easily reclaimed than confined areas. The unit effort expended for confined areas shows a 13 % increase for cutting, 113 % increase for removal and a 14 % increase for hauling. The combined effort expended for

\*Leakage of simulant, during handling, from the ends of the rolls and through holes in the sod layer.

TABLE 3.2  
Breakdown of Productive Effort

Test Area No. (ft <sup>2</sup> )	Man-Power and Effort							
	Cutting		Removing		Combined		Hauling	
No. of Men	Effort $\frac{\text{man-min}}{10^3 \text{ ft}^2}$	No. of Men	Effort $\frac{\text{man-min}}{10^3 \text{ ft}^2}$	No. of Men	Effort $\frac{\text{man-min}}{10^3 \text{ ft}^2}$	No. of Men	Effort $\frac{\text{man-min}/10^3}{10^3 \text{ ft}^2}$	
<u>Open Area Tests</u>								
1 504	1	14.5	2	64.8*	2	79.3	1	126.8
2 504	1	11.9	2	38.4	2	50.3	1	127.9
3 504	1	12.9	2	40.6	2	53.5	1	148.2
Avg. 504	1	13.1	2	39.5	2	61.0	1	134.5
<u>350-700 <math>\mu</math> Particle Size Range</u>								
4 504	1	12.0	2	42.5	2	54.5	1	145.9
5 504	1	12.9	2	48.1	2	61.0	1	143.6
6 504	1	13.8	2	50.1	2	63.9	1	134.3
Avg. 504	1	12.9	2	46.9	2	59.8	1	141.3
<u>44-88 <math>\mu</math> Particle Size Range</u>								
7 504	1	12.7	2	38.4	2	51.1	1	125.3
8 504	1	14.3	2	41.5	2	55.6	1	125.4
9 504	1	12.5	2	47.5	2	60.0	1	110.0
Avg. 504	1	13.2	2	42.5	2	55.6	1	120.4
Grand Avg. 504	1	13.1	2	43.4	2	58.8	1	132.0
<u>Confined Area Tests</u>								
<u>88-177 <math>\mu</math> Particle Size Range</u>								
10 630	1	13.3	3	68.0	3	81.3	1	157.6
11 608	1	11.3	3	103.9	3	115.2	1	147.9
12 702	1	19.3	3	105.1	3	124.4	1	149.9
Avg. 647	1	14.8	3	92.6	3	107.0	1	151.2

\*Because this value was not considered a representative test result, it was not used in computing the average values.

confined areas was 82 % greater than for open areas. These increases are due to obstructions in and around the confined areas and adverse sod moisture conditions.

A comparison of the ranges of effort values noted for the sod cutting tests with those observed for shoveling and tractor scraping of lawns during Target Complex<sup>2,3</sup> experiments follows:

Method	Effort (man-min/10 <sup>3</sup> ft <sup>2</sup> )
Tractor Scraping	35-75
Sod Cutting	56-107
Shoveling	130-360

The results show that (a) on the basis of effort, tractor scraping is superior to sod cutting and that (b) sod cutting is superior to shoveling. However, it is doubtful that either tractor scraping or shoveling\* is as effective as sod cutting due to their lack of spillage control.

### 3.3.2 Average Time Fractions

In order to examine the influence of time invested (irrespective of test area size), time fractions were employed. These time fractions are simply the ratio of the time increment required for a given test phase to the total elapsed time. Using the raw data from Table C.2, (Appendix C) average time fractions were computed for the various test phases and are presented in Table 3.3.

When viewed in this way the differences between open and confined lawn areas appear to decrease. For instance, the time fractions for the cutting phase are the same (0.18) for open and confined areas. The time fractions for removal differed only by 19 %, as indicated at the bottom of the table. The 37 % difference shown for hauling was due partly to a decrease in the distance to the disposal pit. The 9 % decrease in the total productive time fraction and the 57 % increase in the non-productive time fraction are a measure of the overall and the specific effects, respectively, of operational efficiency.

\*A 12 % residual for hand shoveling of lawn planted in sandy loam was reported by Maloney and Meredith of NDL (see Ref. 7). Residual mass was estimated to be 5.7 g/ft<sup>2</sup>.

TABLE 3.3  
Average Time Fractions

Particle Size ( $\mu$ )	Cutting	Removal	Hauling	Total Productive	Non-Productive	Elapsed
<u>Unconfined Areas</u>						
177-350	0.19	0.35	0.35	0.89	0.11	1.0
350-700	0.17	0.31	0.36	0.84	0.16	1.0
44- 88	0.19	0.31	0.35	0.85	0.15	1.0
Average	0.18	0.32	0.35	0.86	0.14	1.0
<u>Confined Areas</u>						
88-177	0.18	0.38	0.22	0.78	0.22	1.0
% Difference	0	+19	-37	-9	+57	-

### 3.4 RECOVERY CREW EXPOSURE

Planning reclamation operations depends upon some means for estimating exposure to recovery crews. From reference 3 the expression\* given for exposure

$$D_2^! = RN_2 D_2 \quad (3)$$

where  $D_2^!$  = actual exposure during recovery

$D_2$  = potential exposure from a free undisturbed radiation field

$RN_2$  = exposure reduction factors (residual number).

\*The sub-scripts are a carry-over from previous work where the 2 distinguishes the recovery phase from the shelter and mission phases.

Potential exposure  $D_2'$  is obtainable from known decay information. Given a proper  $RN_2$  value, the actual exposure  $D_2'$  may be computed. Results from the three land target complex experiments have shown that each method-surface combination is characterized by a particular  $RN_2$  value.

To derive the  $RN_2$  values for sod removal it is necessary to first consider Eq. 3 in the form

$$RN_2 = D_2'/D_2 \quad (4)$$

This ratio can be derived from the exposure rate history of a sod removal experiment. The actual exposure  $D_2'$  will equal the area under the exposure rate curve. It is determined by graphical integration so that

$$D_2' = \sum (I \Delta t_j) \quad (5)$$

where the product  $I \Delta t_j$  represents an incremental exposure strip under the exposure rate history curve (see Fig. 3.3).

The potential exposure  $D_2$  is simply the product of the average initial exposure rate  $I_0^*$  and the recovery interval  $t$ . (For these experiments, which lasted approximately 45 min and employed  $\text{La}^{140}$  (half-life 40.2 hr), no decay correction was assumed to be required.) Therefore, the working equation for obtaining  $RN_2$  experimentally is

$$RN_2 = \frac{\sum (I \Delta t_j)}{I_0 t} \quad (6)$$

### 3.4.1 Exposure Rate History

An exposure-rate history curve was obtained from Test 12 of the sod removal experiment. This test was selected as a typical example of the reclamation effectiveness that can be achieved under similar test conditions.

A portable AN/PDR 27 F (Ser. #4974) survey meter was used to monitor the changing gamma exposure rate  $I_0^*$  alongside the removal crew at 3 feet above the lawn surface. Measurements were taken at 1-min intervals during the 0.75-hr recovery period. The exposure rate history of Fig. 3.3 was plotted from this data. Graphically integrating the exposure rate history curve of Fig. 3.3 and substituting these values into Eq. 6;

\* $I_0$  is obtained from a radiac survey at a height of 3 ft over the contaminated area, whereas  $I_j$  is measured at the receding edge of the shrinking area.

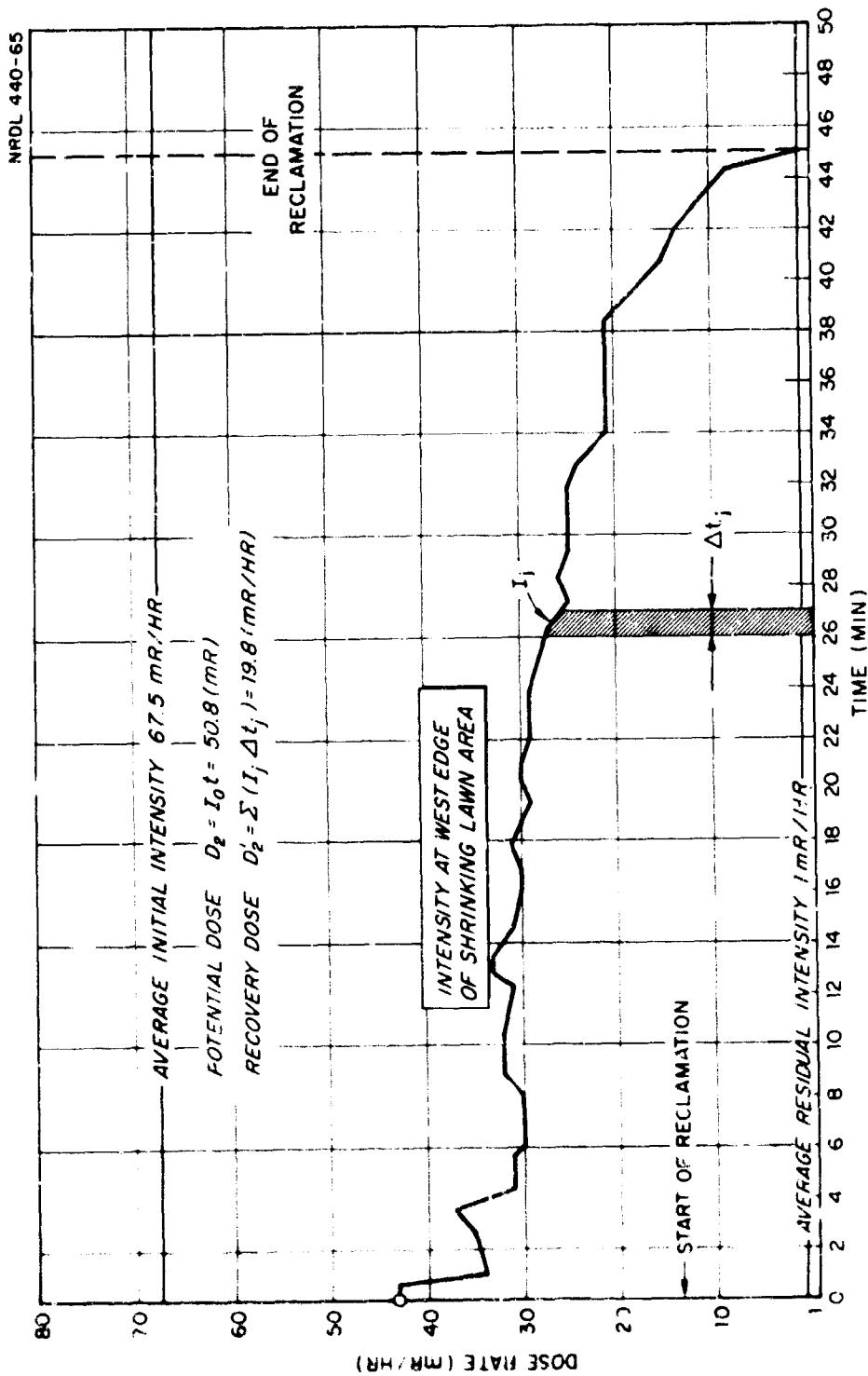


Fig. 3-3 Exposure Rate History for Sod Cutting and Removal

$$RN_2 = \frac{1189.5 \text{ mr/hr} (1/60 \text{ hr})}{67.5 \text{ mr/hr} (3/4 \text{ hr})}$$

$$RN_2 = \frac{19.83 \text{ mr}}{50.6 \text{ mr}} = 0.392$$

Thus for sod removal situations similar to the conditions of Test 12, the actual exposure  $D_2$  (19.83 mr) will be about 40 % of the potential exposure  $D_2$  (50.6 mr). The difference between these two values is due directly to the recovery effort.

A comparison of the exposure to sod cutter crews with those to the shoveling and tractor scraping crews (Target Complex<sup>2,3</sup> results) shows  $RN_2$  values as follows: sod cutting 0.39, shoveling 0.61-0.82, and tractor scraping 0.35-0.9. These values indicate that sod cutting may be the superior method, where exposure to recovery crews is controlling.

### 3.4.2 Unit Man-Exposure

Comparing the above ranking with earlier results it will be noted that sod cutting ranks higher according to the criterion of exposure reduction for recovery crews than to that of effort. It is of interest to see what effect the combination of both criteria would have on the ranking of sod cutting. For convenience let effort  $E$  be defined in terms of man-hr/10<sup>3</sup> ft<sup>2</sup> (rather than man-min/10<sup>3</sup> ft<sup>2</sup>). Also, let  $\bar{I}$  represent an average exposure rate (in r/hr) for a specific recovery period. The product of these two quantities is an expression of the unit man-exposure, thus

$$E \frac{\text{man-hr}}{10^3 \text{ ft}^2} \times \bar{I} \frac{\text{r}}{\text{hr}} = D_m \frac{\text{man-r}}{10^3 \text{ ft}^2} \quad (7)$$

The effort term, of course, is available from the test data. The means for estimating  $\bar{I}$ , however, are not readily apparent. Referring back to Eq. 5, the actual recovery exposure can be said to be equal to the product of an average exposure rate and the recovery interval  $t$ , or

$$D'_2 = \bar{I} t \quad (8)$$

The potential exposure was shown earlier (in Section 3.5) to be closely approximated by the product of the starting exposure rate  $I_0$  and the recovery interval  $t$ , thus

$$D_2 = I_0 t \quad (9)$$

From Eq. 4,  $RN_2 = D'_2/D_2$ . Substituting Eqs. 8 and 9 into this expression and rearranging terms, the average exposure rate becomes

$$\bar{I} = I_0 RN_2 \quad (10)$$

Combining this result with Eq. 7 gives

$$D_m = RN_2 EI_0 \quad (11)$$

as the equation for computing unit man exposure.

When comparing the combined effects of effort E and exposure reduction factors  $RN_2$  expected for various reclamation methods, it is convenient to transpose Eq. 11 so that it reads

$$\frac{D_m}{I_0} = RN_2 E \quad (12)$$

Using this form, in effect, normalizes the results to a unit starting exposure rate. Thus, the product  $RN_2 E$  becomes a unit man-exposure index suitable for judging the relative worth of various reclamation methods, when exposure of recovery crews is controlling.

Effort and  $RN_2$  values from the sod cutting tests and from Target Complex Experiments I and II have been used to construct Table 3.4. The last column contains the results of Eq. 12. From this it is seen that sod cutting ranks between scraping and shoveling. Therefore, the greater exposure reduction capability (smaller  $RN_2$  factor) of sod cutting was not enough to change the order of ranking originally established on the basis of effort expended.

Judging or ranking methods according to the combined criteria of E and  $RN_2$  is more realistic than using either separately, since it takes into account the interaction of two very important operational parameters. In addition the unit man-exposure index provides a means for making rough preliminary calculations of anticipated exposure to recovery personnel. If  $D_m/I_0$  is multiplied by both the area (in  $10^3$  ft<sup>2</sup>) of a contaminated target component and the estimated starting exposure rate and then divided by the number of men per team, an estimate of the exposure per team member will result. This should be of considerable value in the advance planning of radiological recovery operations.

TABLE 3.4

## Comparison of the Combined Effects of Effort and Exposure Reduction Criteria

Method and Task	Unit Effort*, E		Exposure Reduction Factor, $R_{N_2}$		Unit Man Exposure Index*, $D_m/I_o$	
	I	II	I	II	I	II
<u>Sod Cutting</u>	2.08		0.39		0.81	
<u>Target Complex Experiments</u>						
Tractor Scraping:						
Operator	0.57	1.26	0.42	0.35	0.24	0.44
Shovel Man	0.57	1.26	0.64	0.90	0.36	1.13
Hand Shoveling	2.20	6.0	0.82	0.61	1.80	3.66

\*Both E and  $D_m/I_o$  have units of man-hr/10<sup>3</sup> ft<sup>2</sup>. However, the physical significance of the ratio  $D_m/I_o$  is better indicated by retaining all units, i.e., man-r/10<sup>3</sup> ft<sup>2</sup> per r/hr initial radiation.

## 3.5 INFLUENCE OF MACHINE DESIGN

The design features of the sod cutter are suitable for the purpose for which it was originally intended. However, these features may be characterized into advantages and disadvantages when used as a land reclamation method.

3.5.1 Advantages

1. The small size of the sod cutter provides maneuverability in confined areas and around obstructions.

2. The relatively light weight of the sod cutter (in comparison with heavy equipment) permits its use in areas of high moisture content. Heavier equipment could break through the turf and leave streaks of unremoved contamination. The sod cutting machine is also easily transported between jobs by small vehicles such as pick-up trucks, jeeps, or even automobiles.

3. Adjustable blade depth permits the removal of the fallout with a minimum thickness of base soil. The sod cutter accomplishes this in moist turf with a minimum amount of damage to the surface. This prevents spills and redistribution of the unwanted fallout.

4. Convenient location of the throttle and clutch control allows the operator to adjust the speed quickly to changing surface conditions.

### 3.5.2 Disadvantages

1. There is no reverse gear to permit backing out of small or congested areas. Thus, resuming the cutting interrupted by rocks, roots, etc. can only be accomplished by turning the machine around.

2. No provisions have been made in the design of the sod cutter to either roll or push aside the cut sod for easier handling and to expedite successive cuts. As it is, each freshly cut strip must be rolled and removed before the next cut can be made.

3. Recontamination by the cutting blade is inherent in the operation. The cutting blade knifes through the contaminant and turf leaving a streak of residual contamination wherever a cut is made.

## 3.6 INFLUENCE OF LAWN CONDITION

### 3.6.1 Moisture Content

Environmental conditions of moisture content (too wet or dry) would be a determining factor in the usefulness of this method. One particular instance was observed during Test 11. The area was too wet (due to recent rain) during the performance of this test. The unit effort expended for the test was 115 man-min/103 ft<sup>2</sup>. This is approximately 42 % greater than for a comparable area (Test 10) reclaimed two days later under drier conditions. A general comparison of the results in Table 3.1 between open areas (Tests 4 through 9) and confined areas (Tests 10, 11 and 12) shows that, in the latter case the residual mass values tend to run about 50 percent higher than in the former case (in spite of the increased effort). This loss in removal effectiveness was due to spills caused by breakage of the overly moist sod during handling. Similar results might be expected when too little moisture encourages crumbling, and, hence spillage.

### 3.6.2 Rocks and Roots

As noted previously in Section 3.3, rocks and roots can also be responsible for recontamination due to spills. Large rocks (and other hard objects just under the lawn's surface) cause the cutting blade to plane up out of the sod layer. These breaks and skips in the cut create handling problems during the removal phase and lead to spills. Roots from large woody weeds leave holes in the turf, causing still further spillage during rolling and removal.

## 3.7 SOURCE OF ERROR

The main source of error lies in the determinations of mass loading. Initial mass loading measurements were assumed to be  $\pm 5\%$  of the true value, since they were determined by direct weighing methods.

In the case of residual mass determinations, the error was considerably larger. This was caused by a combination of direct and indirect sources of error. As shown in Appendix D, residual mass  $M$  is not measured in the same way as initial mass  $M_0$  but must be estimated from  $M_0$  values and radiation readings. Thus,

$$M = M_0 (R/I)$$

where  $R$  = cpm after reclamation

$I$  = cpr before reclamation

On the average, initial and residual levels  $I$  and  $R$  each reflect the  $\pm 15\%$  error inherent in the shielded gamma detector used in their measurement. These errors combine with that noted for  $M_0$ , such that the error in  $M$  is approximately  $\pm 22\%$ .

## CHAPTER 4

### CONCLUSIONS AND RECOMMENDATIONS

#### 4.1 CONCLUSIONS

The combined operational performance of sod cutting and removal was found to be an effective procedure for lawn reclamation under the conditions studied.

Effective removal can best be accomplished by manually rolling the sod into conveniently sized rolls and loading it into carriers for disposal.

Reclamation effectiveness is governed by initial mass loading, effort expended, and condition of the lawn area.

1. For a given investment of effort, residual mass is a direct function of initial mass loading. That is, residual mass tends to be smaller when initial mass loading is small.

2. Lawn conditions adversely affecting sod cutter performance, in order of decreasing importance, are: (a) confinement of lawns due to size, shape and obstructions, (b) excessive moisture in the sod layer, (c) concentration of rocks and/or woody roots near the surface, and (d), poor grass root system and voids in turf.

Compared to the above factors, the effects of particle size were so slight as to be considered insignificant.

Using effort as a criteria, accessible lawn areas can be reclaimed more efficiently than confined areas.

Of the three phases comprising the lawn reclamation procedure, removal is the controlling phase - when considered in terms of effort required.

Comparisons with previous lawn reclamation tests show the sod cutting procedure to require less effort than shoveling but more effort than tractor scraping.

A recovery crew dose reduction factor,  $R_{N_2}$ , for sod cutting was found to be approximately 0.4, insofar as the radiation contribution from an isolated lawn area is concerned.

#### 4.2 RECOMMENDATIONS

It is recommended that

1. Sod cutters be used in confined areas where other heavy motorized equipment cannot operate efficiently.
2. Feasibility studies be made of some design changes such as: (a) including a reverse gear in the transmission; (b) providing some means for lifting and moving a cut strip of sod a few inches to one side. The latter would enable the operator to continue the cutting phase of the operation without first removing each cut strip.
3. In the event that the reclamation program is revived, consideration should be given to sod cutter experiments on unattended (dry unmowed) lawns, such as would be encountered in a dry climate upon emerging from shelters two or three weeks after a nuclear attack. Evaluation of one of the larger-width (18 in. or 24 in.) cutters for achieving more economical operational rates should be included.

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## APPENDIX A

### PRELIMINARY STUDIES

To determine the significant parameters for sod-cutter machine performance and reclamation performance, 13 preliminary tests were conducted. A non-radioactive fallout simulant was used in mass levels and particle size ranges consistent with requirements for the formal tests. Preliminary tests were conducted on the same types of areas (described in Section 2.4) used for the formal tests.

The objective of the tests was to observe the effects of forward speed, depth of cut, and moisture content on sod cutter performance, and to develop a complete procedure for removing the cut sod. Since no known history of reclamation by sod cutter was available, the design and execution of these tests developed with day-to-day experience. This meant using the observations of one test to adjust and improve the performance for the next test. To reduce the number of tests that could be accommodated on the available test area, a fixed combination of forward speed (1 mph) and depth of cut (1-1/2 in.) was ultimately selected. This combination was then applied to the fallout environmental conditions described in Table 1.1.

Moisture content was determined as follows: The test area was watered liberally (visually determined as being the amount of water generally put on home lawns) prior to the test day. Tests were then run at different periods measured from the time of watering - namely 24, 48, 72, 96 and 120 hr. It was found that the moisture content during the 72 to 96-hr period was most suitable, the moisture retained being just enough to: (a) hold the sod together, (b) minimize the weight of the sod rolls, and (c) provide firm support for the sod cutter and personnel on the test area without breakup of the turf. Shorter delay periods resulted in soggy lawns. Longer periods resulted in sod that was too dry and crumbly.

The theory of land reclamation<sup>1</sup> as applied to previous reclamation procedures also applies to sod removal. That is, the fallout must be removed along with a thin layer of earth. The effectiveness achieved will depend upon the capability of the method to remove the contaminated surface soil. Spills and incomplete coverage will reduce the effectiveness.

The development of a mechanized procedure for removing the cut sod failed. The weight of the skip loader (the lightest piece of motorized equipment available) could not be supported on the moist surface. The large wheels made deep depressions in the soft earth, breaking through the sod surface and packing the soil. These depressions of packed surface seriously hampered the performance of the sod cutter, by preventing it from making uniform cuts. Therefore a manual removal procedure had to be developed, and it is described in Section 2.2.1, items 2 through 4.

#### A.1 RESULTS

Direct visual observations were used almost exclusively in studying the entire preliminary test phase. Therefore, no quantitative data were taken. Although no conclusions could be drawn from these studies they did point out general trends which are summarized as follows:

1. Mass loading and particle size appeared to have no effect on the removal effort. That is, sod cutting, removal, and hauling requires the same amount of unit effort (man-min/f') regardless of the initial mass or particle size.
2. Moisture content is one of the major factors in sod cutting and removal, since it affects the cohesion of the sod. The effectiveness of the sod cutter and of the rolling and handling of the sod is influenced in the following ways.
  - a. Too much moisture permits the wheels of the sod cutter to break through the turf. This causes contamination of the subsoil. The rolls fall apart when handled, causing spills and requiring increased effort. Also, the front wheel treads become clogged with mud. This causes a loss in traction and a complete stoppage of forward progress.
  - b. Too little moisture in the soil may result in hard spots and these will cause the cutter blade to plane upward, thus causing non-uniform cuts. In addition, the sod tends to crumble and break, causing spills. Rolling and handling become extremely difficult if not impossible. Thus, the effort increases while effectiveness decreases.
3. Efficient removal of cut sod with respect to optimum reclamation effectiveness can best be accomplished by manual methods. This consists in manually rolling the cut sod into conveniently sized rolls and, loading it into a motorized carrier for transporting and disposal.

## APPENDIX B

### PHYSICAL AND RADIOLOGICAL PROPERTIES OF FALLOUT SIMULANT

A sample from each of four batches of simulant (one for each nominal particle size range) was sieved into several subsizes or fractions. Each fraction was analyzed to determine certain physical and radiological properties. The results of these measurements are presented in Tables B.1 through B.4. Particle size distributions were determined as described in Section 2.5. Specific activities were measured in the 4- $\pi$  ion chamber (Fig. 2.11).

Ideally the radionuclide tagging process in the production of fallout simulant would provide a constant specific activity ( $\mu\text{c/g}$ ) for all particles in a nominal size range. However, the tagging process used consisted of spraying a solution of radioactive  $\text{Ia}^{140}$  onto the surface of the bulk carrier material.<sup>5</sup> If uniform coverage is achieved, the amount in microcuries ( $\mu\text{c}$ ) of radioactivity on a particle will be proportional to the surface area. The radioactivity can be related to volume or mass (for uniform material density) for spherical particles of diameter  $d$  as follows:

$$\frac{\text{Activity}}{\text{Mass}} \propto \frac{\text{Surface}}{\text{Volume}} = \frac{\pi d^2}{\frac{\pi d^3}{6}} = K (1/d) \quad \text{B.1}$$

where  $K$  is a proportionality constant between specific activity ( $\mu\text{c/g}$ ) and the reciprocal of the particle diameter ( $1/d$ ). If this idealized relationship prevailed in practice, Eq B.1 would be a straight line with slope  $K$  in linear coordinates (specific activity vs reciprocal diameter). However, the above idealized inverse proportionality of activity-mass to particle diameter is somewhat altered in the actual tagging process because particles are non-spherical or become agglomerated. These alterations of shifts in size distributions are shown in the 3rd and 4th columns (weight analysis) of Tables B.1 through B.4.

TABLE B.1

Physical and Radiological Properties of Fallout Simulant Batch No. 1  
Having a Nominal Particle Size Range of 44  $\mu$  to 88  $\mu$

Sieve (U. S. Mesh)	Size ( $\mu$ )	Weight Analysis		Radioactivity Analysis (%)	% Act. % Mass
		Raw Material (%)	Tagged Material (%)		
150	104	0.6	0.68	0.74	1.1
170	88	3.1	2.02	1.45	0.72
			*		
200	74	33.0	24.59	18.47	0.75
250	62	25.6	25.56	21.98	0.86
270	53	15.2	20.22	20.00	0.99
325	44	17.7	22.01	26.17	1.19
Pan	< 44	5.0	4.71	11.31	2.40
			92.38	85.62	

Date Batch Mixed - 10/10/63  
Specific Activity at Mixing Time - 7.6  $\mu$ c/g

\*Numbers between the lines represent at least 88 % of the material,  
called the Control Percentage.

TABLE B.2

Physical and Radiological Properties of Fallout Simulant Batch No. 2  
Having a Nominal Particle Size Range 88  $\mu$  to 177  $\mu$

Sieve (U.S. Mesh)	Size ( $\mu$ )	Weight Analysis		Radioactivity Analysis	% Act. % Mass
		Raw Material (%)	Tagged Material (%)		
65	208	0.63	3.53	2.066	0.59
80	177	4.56	3.58	2.64	0.74
100	149	12.83	-	0	
			*		
115	125	32.70	38.98	33.47	0.86
150	104	29.40	29.27	30.13	1.03
170	88	12.13	19.53	23.46	1.20
200	74	6.77	4.71	7.53	1.60
Pan	< 74	1.13	0.21	0.70	3.33
			87.78	87.06	

Date Batch Mixed - 10/16/63

Specific Activity at Mixing Time - 11.4  $\mu$ c/g

\*Numbers between the lines represent at least 88 % of the material,  
called the Control Percentage.

TABLE B.3

Physical and Radiological Properties of Fallout Simulant Batch No. 3  
Having a Nominal Particle Size Range 177  $\mu$  to 350  $\mu$

Sieve (U.S. Mesh)	Size ( $\mu$ )	Weight Analysis		Radioactivity Analysis (%)	% Act. % Mass
		Raw Material (%)	Tagged Material (%)		
35	500	0.03	0.04	0.063	1.58
40	420	0.44	0.22	0.14	0.63
45	354	5.58	* 9.34	6.74	0.72
50	297	24.27	31.05	24.82	0.80
60	250	33.80	38.08	37.03	0.97
80	177	31.57	20.22	27.58	1.36
100	149	2.80	0.97	2.64	2.72
120	125	0.71	0.12	0.51	4.25
Pan	< 125	0.67	0.09	0.49	5.44
			98.69	96.17	

Date Batch Mixed 9/18/63

Specific Activity at Mixing Time - 29.37  $\mu$ c/g

\*Numbers between the lines represent at least 80 % of the material,  
called the Control Percentage.

TABLE B.4

Physical and Radiological Properties of Fallout Simulant Batch No. 4  
Having a Nominal Particle Size Range 350  $\mu$  to 700  $\mu$

Sieve (U.S. Mesh)	Size ( $\mu$ )	Weight Analysis		Radioactivity Analysis (%)	% Act. % Mass
		Raw Material (%)	Tagged Material (%)		
25	707	0.1	0.01	0.02	2.0
30	595	1.0	0.42	0.30	0.71
35	500	12.3	9.25	7.58	0.82
40	420	33.3	27.76	24.60	0.89
45	354	43.6	51.31	51.24	1.00
50	297	9.1	9.98	13.84	1.39
60	250	0.5	0.70	1.16	1.66
70	210	-	0.07	0.22	3.14
Pan	< 210	0.2	0.23	1.05	4.57
			98.30	97.26	

Date Batch Mixed - 9/24/64

Specific Activity at Mixing - 12  $\mu$ c/g

\*Numbers between the lines represent at least 85 % of the material,  
called the Control Percentage.

Relative specific activity (% activity/% mass) for the sieve fractions of each batch is given in the last column of Tables B.1 through B.4. These have been plotted against  $1/d$  (computed from sieve fraction mid-size) to test the validity of Eq B.1. The resultant curves are shown in Fig. B.1. A logarithmic plot was used in order to provide convenient comparison of all four batches.

For the curves to obey Eq B.1, they should all be straight parallel lines having a common slope of one. This means that on a linear plot they would also be straight lines, but each curve would radiate from the origin at a different (but constant) slope. The curves in Fig. B.1 do not at first appear to satisfy these conditions. Reviewing Tables B.1 through B.4 it is seen that at least 88 % of the mass and activity of each sample is contained in three or four sieve fractions. These are shown as solid data points in Fig. B.1 and represent the control percentages.\* Straight line curves can be fitted to these controlling points as shown by the heavy lines. Furthermore they meet the above conditions dictated by Eq B.1.

\*The control percentages (shown at the bottom of the tables) include the fractions within the nominal Particle Size Range and, in some cases, one additional fraction if it approaches 10 % of the sample weight.

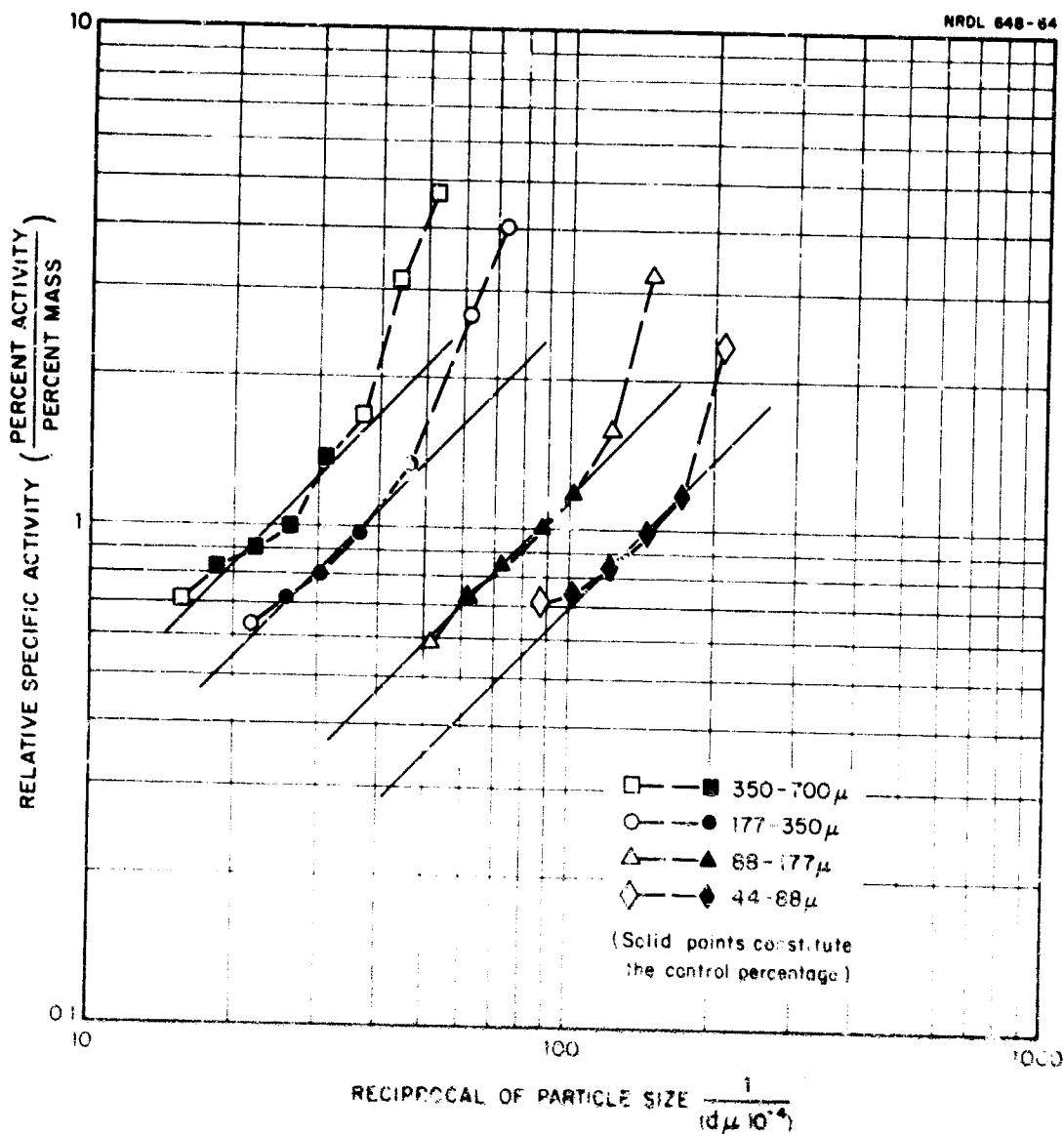


Fig. B.1 Comparison of the Specific Activity Associated with the Size Distribution of Each Fallout Simulant Batch.

## APPENDIX C

### RAW TEST DATA

#### C.1 RADIATION DATA

Tables C.1.1-C.1.12 present for each test the radiation measurements obtained at the monitoring locations (see Fig. 2.6) on the test area. The measurements have been background-corrected and decay-corrected to the zero time indicated in the upper left-hand portion of the table. All measurements were taken with the mobile shielded gamma detector described in Chapter II of this report.

#### C.2 COMPIRATION OF BASIC DATA

The sod cutting and removal experiments were timed in detail for each phase (cutting, removing and hauling) of the operation. Table C.2 presents the raw data as time in minutes required to complete each phase of the tests. The total productive time is the summation of the times expended during each phase. The elapsed time is the recorded time from the beginning to the end of a test and includes non-productive time. Therefore, the latter is the difference between the elapsed time and the total productive time.

TABLE C.1.1  
Corrected Data for Sod Cutting and Removal

Test No. 1  
Date, 3/17/63  
Zero Time 9/17/1200

Particle Size 177-350  $\mu$   
Initial Mass 25.2 g/ft<sup>2</sup>  
Test Section Size 504 ft<sup>2</sup>

Radiation Readings (c/m)					
<u>Initial</u>					
25478 (1)	32189 (2)	31843 (3)	32083 (4)	31509 (5)	29034 (6)
42565 (7)	47537 (8)	43670 (9)	41857 (10)	5097 (11)	32720 (12)
33331 (13)	39440 (14)	39744 (15)	43884 (16)	42936 (17)	38870 (18)
Average 37400 $\pm$ 6566					
<u>Residual</u>					
898 (1)	563 (2)	521 (3)	516 (4)	588 (5)	848 (6)
706 (7)	1070 (8)	2065 (9)	1028 (10)	1652 (11)	1480 (12)
740 (13)	1279 (14)	501 (15)	815 (16)	1543 (17)	1034 (18)
Average 992 $\pm$ 452					
% Removed 96.5 $\pm$ 1.86					

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.2  
Corrected Raw Data for Sod Cutting and Removal

Test No. 2  
Date, 9/18/63  
Zero Time 9/17/1200

Particle Size 177-350  $\mu$   
Initial Mass 51.8 g/ft<sup>2</sup>  
Test Section Size 504 ft<sup>2</sup>

<u>Radiation Readings (c/m)</u>					
<u>Initial</u>					
85618 (1)	97006 (2)	92118 (3)	87589 (4)	77113 (5)	68487 (6)
94367 (7)	105315 (8)	108815 (9)	102978 (10)	97089 (11)	69781 (12)
93997 (13)	112213 (14)	109200 (15)	109566 (16)	114794 (17)	134747 (18)
Average 97830 $\pm$ 16590					
<u>Residual</u>					
3110 (1)	2205 (2)	1215 (3)	1352 (4)	901 (5)	1078 (6)
1419 (7)	1479 (8)	2269 (9)	2524 (10)	1661 (11)	1607 (12)
1169 (13)	2435 (14)	1583 (15)	1784 (16)	1930 (17)	1268 (18)
Average 1723 $\pm$ 584					
% Removed 98.2 $\pm$ 0.95					

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.3

## Corrected Raw Data for Sod Cutting and Removal

Test No. 3  
 Date, 9/19/63  
 Zero Time 9/17/1200

Particle Size 177-350  $\mu$   
 Initial Mass 92.3 g/ft<sup>2</sup>  
 Test Section Size 504 ft<sup>2</sup>

## Radiation Readings (c/m)

<u>Initial</u>					
198860 (1)	187352 (2)	200374 (3)	175031 (4)	188276 (5)	184266 (6)
162261 (7)	176612 (8)	178436 (9)	171261 (10)	170270 (11)	155920 (12)
165239 (13)	186439 (14)	192999 (15)	186401 (16)	187857 (17)	158170 (18)

Average 179227  $\pm$  13300

<u>Residual</u>					
3434 (1)	3254 (2)	2207 (3)	1994 (4)	3233 (5)	2833 (6)
2207 (7)	2755 (8)	1888 (9)	2512 (10)	298 (11)	4188 (12)
3151 (13)	3608 (14)	1923 (15)	4507 (16)	1301 (17)	2207 (18)

Average 2739 + 857  
% Removed 98.5  $\pm$  1.72

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.4  
Corrected Raw Data for Sod Cutting and Removal

Test No. 4  
Date, 9/24/63  
Zero Time 9/24/1200

Particle Size 350-700  $\mu$   
Initial Mass 21.6 g/ft<sup>2</sup>  
Test Section Size 504 ft<sup>2</sup>

<u>Radiation Readings (c/m)</u>					
<u>Initial</u>					
42605 (1)	47030 (2)	45551 (3)	46935 (4)	47066 (5)	33053 (6)
35049 (7)	32993 (8)	41003 (9)	43058 (10)	43455 (11)	41859 (12)
40584 (13)	43591 (14)	42693 (15)	41911 (16)	39854 (17)	37255 (18)
Average 41419 $\pm$ 4400					
<u>Residual</u>					
653 (1)	632 (2)	452 (3)	593 (4)	496 (5)	490 (6)
664 (7)	231 (8)	560 (9)	402 (10)	323 (11)	258 (12)
224 (13)	246 (14)	624 (15)	520 (16)	228 (17)	168 (18)
Average 431 $\pm$ 173					
% Removed 98.9 $\pm$ 0.46					

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.5

## Corrected Raw Data for Sod Cutting and Removal

Test No. 5  
 Date, 9/25/63  
 Zero Time 9/24/1200

Particle Size 350-700  $\mu$   
 Initial Mass 50 g/ft<sup>2</sup>  
 Test Section Size 504 ft<sup>2</sup>

## Radiation Readings (c/m)

<u>Initial</u>					
87616 (1)	93946 (2)	95570 (3)	92637 (4)	84206 (5)	87581 (6)
59408 (7)	71306 (8)	81297 (9)	82731 (10)	88656 (11)	83159 (12)
84626 (13)	83425 (14)	71217 (15)	72994 (16)	75583 (17)	73156 (18)

Average 81620  $\pm$  9400

<u>Residual</u>					
806 (1)	716 (2)	1007 (3)	1049 (4)	970 (5)	1310 (6)
2203 (7)	861 (8)	1191 (9)	958 (10)	723 (11)	938 (12)
2207 (13)	1859 (14)	763 (15)	908 (16)	906 (17)	2002 (18)

Average 1188  $\pm$  511

% Removed 28.5  $\pm$  0.77

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.6  
Corrected Raw Data for Sod Cutting and Removal

Test No. 6

Date, 9/26/63

Zero Time 9/24/1200

Particle Size 350-700  $\mu$

Initial Mass 94 g/ft<sup>2</sup>

Test Section Size 504 ft<sup>2</sup>

Radiation Readings (c/m)

Initial

139982 (1)	137913 (2)	133226 (3)	131733 (4)	93721 (5)	126607 (6)
139335 (7)	161158 (8)	165415 (9)	155936 (10)	116746 (11)	130540 (12)
143819 (13)	132400 (14)	121894 (15)	122525 (16)	108311 (17)	(18)

Average 133076  $\pm$  14720

Residual

721 (1)	2123 (2)	869 (3)	1079 (4)	1345 (5)	2367 (6)
1811 (7)	1596 (8)	1970 (9)	1453 (10)	2094 (11)	659 (12)
1091 (13)	1106 (14)	2127 (15)	1386 (16)	1768 (17)	1412 (18)

Average 1499  $\pm$  517

% Removed 98.9  $\pm$  0.59

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.7  
Corrected Raw Data for Sod Cutting and Removal

Test No. 7  
Date, 10/9/63  
Zero Time 10/8/1200

Particle Size 44-88  $\mu$   
Initial Mass 23.4 g/ft<sup>2</sup>  
Test Section Size 504 ft<sup>2</sup>

<u>Radiation Readings (c/m)</u>					
<u>Initial</u>					
50860 (1)	69999 (2)	72098 (3)	64207 (4)	65292 (5)	45504 (6)
56355 (7)	63444 (8)	59842 (9)	79439 (10)	65390 (11)	64800 (12)
46859 (13)	56072 (14)	62473 (15)	71588 (16)	63248 (17)	58548 (18)
Average 62001 $\pm$ 8785					
<u>Residual</u>					
301 (1)	374 (2)	448 (3)	623 (4)	766 (5)	948 (6)
395 (7)	631 (8)	551 (9)	485 (10)	344 (11)	436 (12)
482 (13)	453 (14)	728 (15)	647 (16)	432 (17)	696 (18)
Average 549 $\pm$ 185					
% Removed 99.1 $\pm$ 0.47					

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.8  
Corrected Raw Data for Sod Cutting and Removal

Test No. 8  
Date, 10/10/63  
Zero Time 10/8/1200

Particle Size 44-88  $\mu$   
Initial Mass 50 g/ft<sup>2</sup>  
Test Section Size 504 ft<sup>2</sup>

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Radiation Readings (c/m)

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Initial

104831 (1)	105322 (2)	114110 (3)	108147 (4)	108474 (5)	96452 (6)
108049 (7)	111812 (8)	121414 (9)	117176 (10)	110996 (11)	108353 (12)
94643 (13)	104299 (14)	112241 (15)	106431 (16)	113060 (17)	95064 (18)

Average 107860  $\pm$  7205

Residual

897 (1)	811 (2)	1142 (3)	889 (4)	1163 (5)	944 (6)
1920 (7)	967 (8)	984 (9)	889 (10)	595 (11)	788 (12)
415 (13)	678 (14)	969 (15)	661 (16)	839 (17)	924 (18)

Average 915  $\pm$  311  
% Removed 99.0  $\pm$  0.42

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Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.9

## Corrected Raw Data for Sod Cutting and Removal

Test No. 9  
 Date, 10/12/63  
 Zero Time 10/8/1200

Particle Size 44-88  $\mu$   
 Initial Mass 109.9 g/ft<sup>2</sup>  
 Test Section Size 504 ft<sup>2</sup>

## Radiation Readings (c/m)

Initial

274590 (1)	320689 (2)	290997 (3)	300121 (4)	316287 (5)	271476 (6)
287443 (7)	307592 (8)	320321 (9)	321797 (10)	322068 (11)	260201 (12)
253824 (13)	276143 (14)	282735 (15)	288433 (16)	281846 (17)	245848 (18)

Average 390133  $\pm$  23710Residual

1834 (1)	3651 (2)	2630 (3)	2744 (4)	1833 (5)	2278 (6)
2215 (7)	2232 (8)	5542 (9)	6264 (10)	3165 (11)	2278 (12)
1999 (13)	1658 (14)	4314 (15)	3455 (16)	2852 (17)	1771 (18)

Average 2868  $\pm$  1202  
% Removed 99.3  $\pm$  0.42

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Note: Numbers in parenthesis designate monitoring stations.

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TABLE C.1.10

## Corrected Raw Data for Sod Cutting and Removal

Test No. 10  
 Date, 10/16/63  
 Zero Time 10/15/1200

Particle Size 88-177  $\mu$   
 Initial Mass 24 g/ft<sup>2</sup>  
 Test Section Size 504 ft<sup>2</sup>

Radiation Readings (c/m)					
<u>Initial</u>					
58599 (1)	63629 (2)	61769 (3)	68951 (4)	65812 (5)	61605 (6)
66292 (7)	68806 (8)	69655 (9)	65994 (10)	64222 (11)	50298 (12)
60596 (13)	54736 (14)	60663 (15)	54305 (16)	(17)	N.D. (18)
Average 59797 $\pm$ 5617					
<u>Residual</u>					
N.D. (1)	1242 (2)	1013 (3)	661 (4)	1422 (5)	517 (6)
1029 (7)	1461 (8)	845 (9)	879 (10)	695 (11)	763 (12)
446 (13)	763 (14)	1645 (15)	1705 (16)	938 (17)	N.D. (18)
Average 1002 $\pm$ 388					
% Removed 98.3 $\pm$ 1.02					

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.11  
Corrected Raw Data for Sod Cutting and Removal

Test No. 11  
Date, 10/17/63  
Zero Time 10/15/1200

Particle Size 88-177  $\mu$   
Initial Mass 60.9 g/ft<sup>2</sup>  
Test Section Size 504 ft<sup>2</sup>

Radiation Readings (c/m)

<u>Initial</u>					
170618 (1)	187336 (2)	179813 (3)	176831 (4)	183546 (5)	163643 (6)
170238 (7)	202711 (8)	180269 (9)	175282 (10)	180538 (11)	166146 (12)
149621 (13)	162060 (14)	168524 (15)	170075 (16)	166229 (17)	158968 (18)

Average 172913  $\pm$  12030

<u>Residual</u>					
1575 (1)	2363 (2)	2351 (3)	1264 (4)	1929 (5)	2054 (6)
1442 (7)	1511 (8)	2115 (9)	1958 (10)	1527 (11)	1676 (12)
1631 (13)	1482 (14)	2054 (15)	1531 (16)	1814 (17)	2317 (18)

Average 1813  $\pm$  339  
% Removed 98.5  $\pm$  0.92

Note: Numbers in parenthesis designate monitoring stations.

TABLE C.1.12  
Corrected Raw Data for Sod Cutting and Removal

Test No. 12    Particle Size 88-177  $\mu$   
 Date, 10/18/63                                      Initial Mass 98.5 g/ft<sup>2</sup>  
 Zero Time 10/15/1200                              Test Section Size 504 ft<sup>2</sup>

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<u>Radiation Readings (c/m)</u>					
<u>Initial</u>					
206707 (1)	244683 (2)	235855 (3)	245251 (4)	26058 (5)	168518 (6)
160617 (7)	168086 (8)	184589 (9)	169815 (10)	N.D. (11)	157477 (12)
124205 (13)	213824 (14)	236378 (15)	250953 (16)	257234 (17)	228299 (18)
Average 206676 $\pm$ 42420					
<u>Residual</u>					
2736 (1)	3461 (2)	2931 (3)	2305 (4)	3180 (5)	3521 (6)
1889 (7)	1381 (8)	2149 (9)	2345 (10)	N.D. (11)	2590 (12)
2821 (13)	7998 (14)	6184 (15)	8186 (16)	5139 (17)	2718 (18)
Average 3610 $\pm$ 2037					
% Removed 98.8 $\pm$ 1.37					

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Note: Numbers in parenthesis designate monitoring stations.

TABLE C.2  
Time and Motion Data

Test No.	No. of Strips	No. of Pay-Loader Trips	Time (minutes)					
			Cutting (1 man)	Removing (1 man)	Hauling (1 man)	Total Productive	Elapsed	Non-Productive
<u>177-350 <math>\mu</math> Particle Size Range</u>								
1	16	3	7.32	16.35	11.7	35.37	40.0	4.63
2	15	4	6.02	9.67	11.8	27.49	30.0	2.51
3	17	4	6.52	10.33	15.9	30.75	35.0	4.25
Avg.	16	3.67	6.62	12.12	12.47	31.20	35.0	3.80
<u>350-700 <math>\mu</math> Particle Size Range</u>								
4	15	4	6.03	10.70	13.9	30.63	36.0	5.37
5	16	4	6.52	12.12	13.9	32.54	37.0	4.46
6	16	4	6.98	12.63	13.2	32.81	41.0	8.19
Avg.	15.67	4	6.51	11.82	13.67	32.0	38.0	6.00
<u>44-88 <math>\mu</math> Particle Size Range</u>								
7	16	4	6.42	9.66	12.5	28.58	36.0	7.42
8	16	4	7.22	10.47	12.7	30.39	33.0	2.61
9	16	4	6.32	11.97	11.2	29.49	37.0	7.51
Avg.	16	4	6.65	10.70	12.13	29.49	35.3	5.85
<u>88-177 <math>\mu</math> Particle Size Range</u>								
10	42	5	8.40	14.28*	13.40	36.08	54.0	17.92
11	22	4	6.87	21.05*	10.25	38.17	51.0	12.83
12	46	5	13.53	24.60*	10.10	48.23	52.0	3.77
Avg.	36.67	4.67	9.60	19.08*	11.25	40.83	52.3	11.51

\*On tests 10-12 an additional man was used during removal phase.

## APPENDIX D

### CONVERSION OF RADIATION MEASUREMENTS TO CORRECTED ZERO-TIME COUNTS AND MASS UNITS

#### D.1 ZERO-TIME COUNT CONVERSION

Because the amount of radiation from tracers such as La<sup>140</sup> varies with time, it is customary to normalize radiation measurements to a common reference or zero-time. For these tests zero time was usually taken as 1200 hrs on the day the simulant was produced. For a given week of testing, the survey data were converted to zero-time as follows:

Starting with an average raw count  $\bar{X}$ , the corrected zero-time count  $\bar{X}_c$  may be derived from the following expression:

$$\bar{X}_c = \frac{\bar{X} (\text{Std. Factor}) - (\text{Nat. Bkgd})(\text{Crctd. Art. Bkgd.})}{\text{Decay Factor}}$$

The standard factor compensates for fluctuations in instrument response by adjusting all raw counts ( $X$ 's) with respect to a standard Co<sup>60</sup> source. The standard factor is computed from the ratio of readings taken from this source. Thus,

$$\text{Std. Factor} = \frac{18,000 \text{ cpm}}{\text{Avg Co}^{60} \text{ reading}}$$

where 18,000 is an arbitrary reference value approximately equal to the expected daily average standard count. The denominator is the average of standard counts taken before and after the survey values comprising  $\bar{X}$  are obtained.

The decay factor simply corrects for the known decay characteristics of the La<sup>140</sup> tracer. The decay factor is based on the 40.2-hr half-life and is calculated over the time interval extending from the selected zero-time to the mid-time of a given test run.

The background count is made up of two values. The first is the natural background which is the calibrated response of the instrument. Natural background is a constant value of 22 cpm (for the instrument used and described in Section 2.7). The second is the artificial calculated background caused by residual contamination from previous tests. It tends to increase during a series of tests. All averages of raw background counts must be adjusted for instrument response, radioactive decay and natural background in the same way as  $\bar{X}$  values. This converts these average readings to the corrected artificial background value shown in the above expression for  $\bar{X}_c$ .

#### D.2 RADIATION TO MASS UNIT CONVERSION

Since land reclamation data is interpreted in terms of mass loading, it was necessary to convert the above, corrected radiation counts into mass units of grams per square foot. Initial mass loading values  $\bar{M}_o$  were obtained directly by weighing the simulant dispersed over known areas. Obviously this was not possible for procuring residual mass loadings after reclamation.

The residual mass ( $\text{g}/\text{ft}^2$ ) was determined as follows. Starting with the corrected initial zero-time count  $\bar{I}$  and the corrected residual zero-time  $\bar{R}$ , the residual mass  $\bar{M}$  was derived from the expression:

$$\bar{M} = \bar{R} (\bar{M}_o / \bar{I})$$

This, of course, assumes that the ratio of mass loading to radiation intensity is a constant for a given batch of simulant. The ratio  $\bar{M}_o / \bar{I}$  provides the estimate of this constant.

## APPENDIX E

### OPERATING CHARACTERISTICS OF RYAN SOD CUTTER, JR.

The information listed below was obtained from the manufacturer's information brochures describing the Ryan Sod Cutter, Jr.

Cutter Model - Ryan, Jr. (JR 3)

Manufacturer - Landscaping Equipment Company  
Division of K and N Machine Works, Inc.  
871 Edgerton Street  
St. Paul 1, Minnesota

Engine - Gasoline, 5-1/2 h.p., 4-cycle, Briggs & Stratton

Cutting Speed - up to 100 ft/min

Cutter Blade - 12 in. wide

Thickness of cut - Adjustable depth 1/4-2-1/4 in.

Controls - Engine clutch and throttle located on handle

Gears - One forward speed plus neutral

Drive Wheels - Two 4-1/2 x 8-in. solid rubber "knobby" tread tires

Weight - 245 lb

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A sod-cutting machine was evaluated for its usefulness in the radiological reclamation of small lawn areas - some of which were confined by sidewalks, trees and buildings. Fallout conditions were simulated by contaminating lawn test areas with radio-traced sand. Nominal particle size ranges of 44-88  $\mu$ , 88-177  $\mu$  177-350  $\mu$  and 350-700  $\mu$  were used. This fallout simulant was dispersed at nominal concentrations of 25, 50 and 100 g/ft<sup>2</sup>, respectively.

Reclamation effectiveness of sod cutting was dependent upon machine factors (blade depth), soil characteristics (moisture content) and fallout simulant properties (mass loading). The least effective sod removal results were obtained in confined lawns with high moisture content and heavy rock concentrations. The best sod cutting and removal effectiveness results were obtained on more accessible lawns having less moisture content and only a light concentration of rocks. Simulant particle size was found to have little, if any, effect upon reclamation performance either with respect to effort required or removal effectiveness achieved.

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Fallout removal Land reclamation Sod removal efficiency						
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